Weather Note

AN OBSERVATION OF ARCUS AND FUNNEL CLOUDS OVER CHESAPEAKE BAY

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ABSTRACT

Photographs of arcus and funnel clouds which occurred near the western shore of Chesapeake Bay on the afternoon of September 3, 1961, are presented. An attempt is made to relate the unusual cloud phenomena to meteorological events of meso-scale dimensions.

1. INTRODUCTION

Spectacular cloud formations are not unique in the Chesapeake Bay area. However, at approximately 1600 EST September 3, 1961, the author had the good fortune to photograph two rare cloud formations from the western shore of the Bay in Calvert County, Maryland. Two and possibly three funnels developed shortly after the passage of an arcus cloud. The associated weather observed at the time indicated that probably two instability lines were passing the area. The primary purpose of this paper is to present the cloud observations. Additionally, a meso-scale synoptic analysis of surface meteorological conditions is made in order to investigate the causes of the cloud phenomena on a compatible scale.

2. VISUAL OBSERVATIONS

The location of the camera (see fig. 1) was on a cliff approximately 100 feet above the Bay. The area is heavily wooded and trees prevent observation of the entire sky. The first photograph taken is figure 2. The lower cloud appears to have a slightly downward curvature (arc ABC); there is a curved band in a different plane above the low cloud (arc DEF). A series of photographs, in rapid sequence, was then taken between 1555 and 1600 EST, which reveals a complete, low, arc-like cloud. Figure 3 is a composite made from these four photographs.[1] According to the International Cloud Atlas [1], such a phenomenon is called "arcus",[2] and is a "supplementary feature" associated with cumulonimbus, rather than a separate cloud type. The swirls along the edge of the cloud, particularly to the east and east-southeast (fig. 3) indicate an extremely turbulent condition. The ragged elements appeared to pulsate up and down, as the cloud moved rapidly from north to south. The arcus then appeared to be lost in an overcast of chaotic low cloud moving in various directions.

Between 1600 and 1605 EST, photographs were taken with the camera pointed toward the southeast, showing the development of two and possibly three funnel clouds (figs. 4, 5, and 6).[3] It is estimated that the funnels were two to three miles from the camera location as shown in figure 1. The estimated positions of the arcus and funnels shown in this figure are not simultaneous. When the funnels were photographed, the author, at the indicated camera location, could no longer discern the arcus. The

[1] Technical data: Rolleiflex camera, hand-held; exposure 1/50 sec. $f/5.6$, Verichrome Pan film, normal development in Microdol.

[2] Definition of "arcus" from [1]: "A dense, horizontal roll with more or less tattered edges, situated on the lower front part of certain clouds and having, when extensive, the appearance of a dark, menacing arch. This supplementary feature occurs with Cumulonimbus and, less often, with Cumulus."

[3] Photographic data same as for figures 2 and 3 except lens opening was $f/4$.

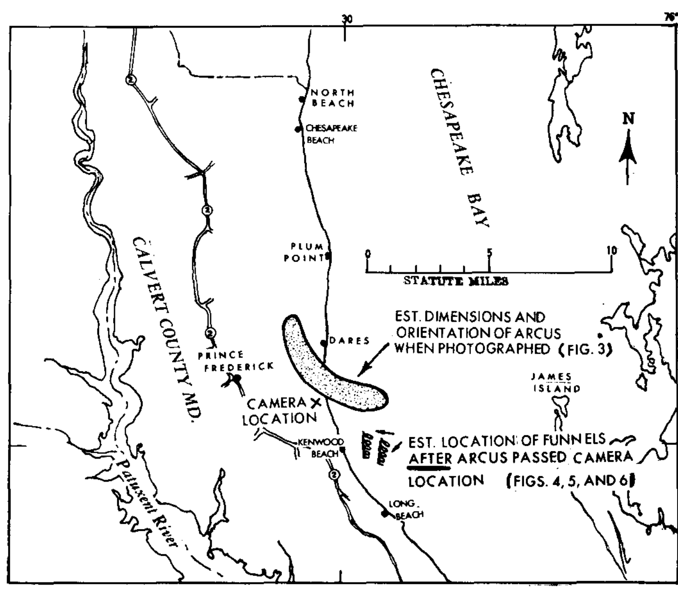


FIGURE 1.—Location of camera and estimated location of cloud phenomena.

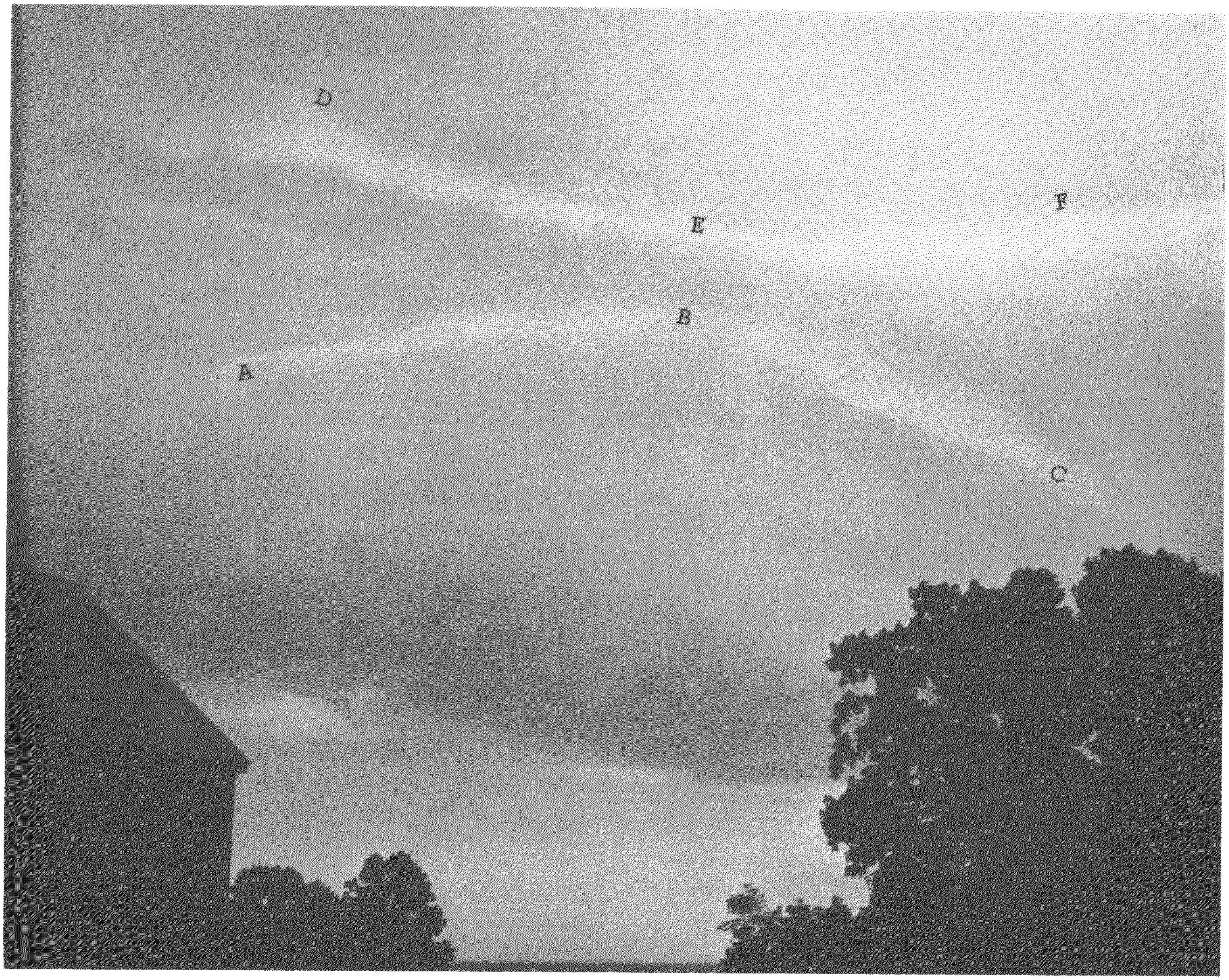


Figure 2.—Arcus cloud approaching. Camera pointed east-northeast. September 3, 1961, 1550-1555 EST. Labels indicate curvature (see text).

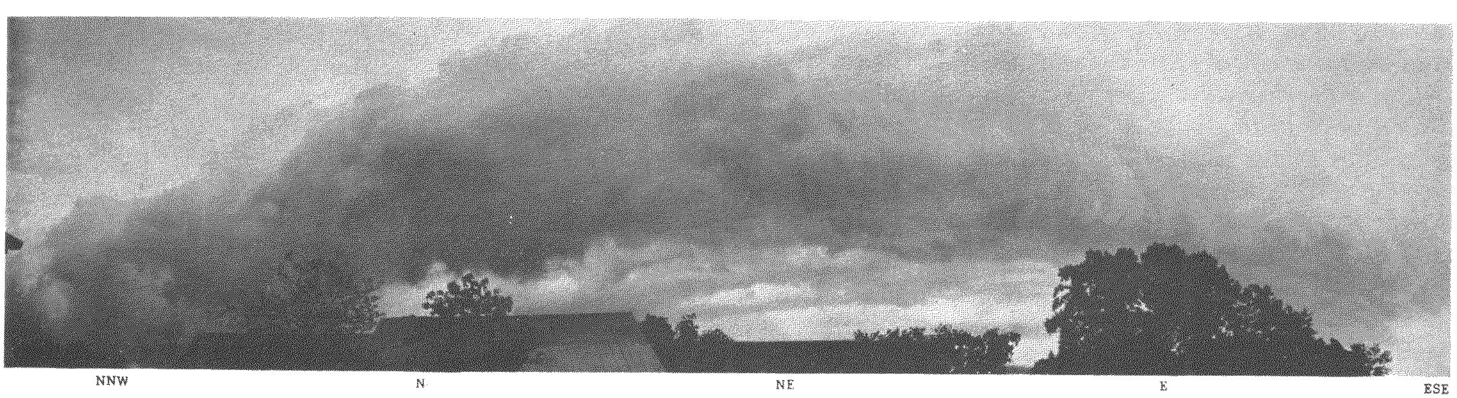


Figure 3.—The arcus cloud. Direction with respect to camera is indicated under appropriate portions of the photograph. September 3, 1961, 1555-1600 EST. This composite was made from four separate exposures.

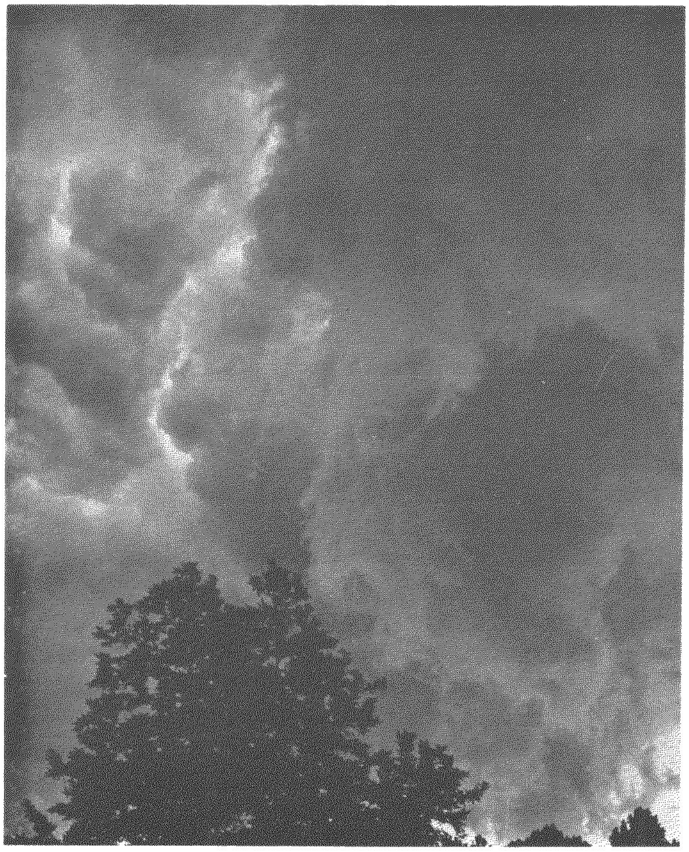


FIGURE 4.—Funnel clouds, incipient stage. Camera pointed southeast. September 3, 1961, 1600–1605 EST.

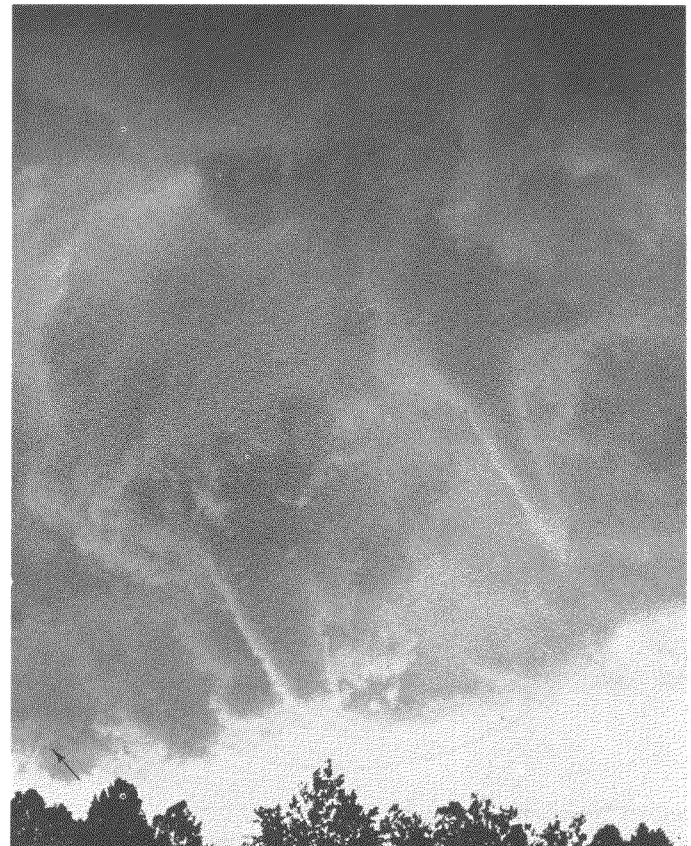


FIGURE 5.—Funnel clouds, mature stage. Other data same as figure 4. Possible third funnel indicated by arrow.

funnels moved slowly toward the south, and lasted approximately two minutes. A man located several miles to the south claimed that he saw the funnels "draw water out of the Bay", but trees prevented a view of the Bay beneath the funnels from the camera location. No noise or other unusual phenomena were noted by the author.

With the onset of the cloud cover, the temperature dropped an estimated 10° F., from the middle 90's, at the camera location. The wind was highly variable, southwest to northwest at 10–25 m.p.h. (estimated); whitecaps on the Bay moving from south to north, after the funnel clouds occurred, indicated a strong south wind over the Bay at that time. No rain fell at the camera location until the funnel clouds dissipated; then a light rain shower occurred lasting for 10–15 minutes, and passing from west to east. The temperature fell another 10°–15° with the onset of the rain. Beginning with the rain, severe cloud-to-ground lightning occurred near and to the south of camera location, moving from west to east. This activity persisted for at least 20 minutes.

3. MESO-SCALE SYNOPTIC ANALYSIS

Two sources of data were used in this analysis: time lapse 16-mm. photographs of the PPI scope of the WSR–57

FIGURE 6.—Funnel clouds, decaying stage. Other data same as figures 4 and 5.

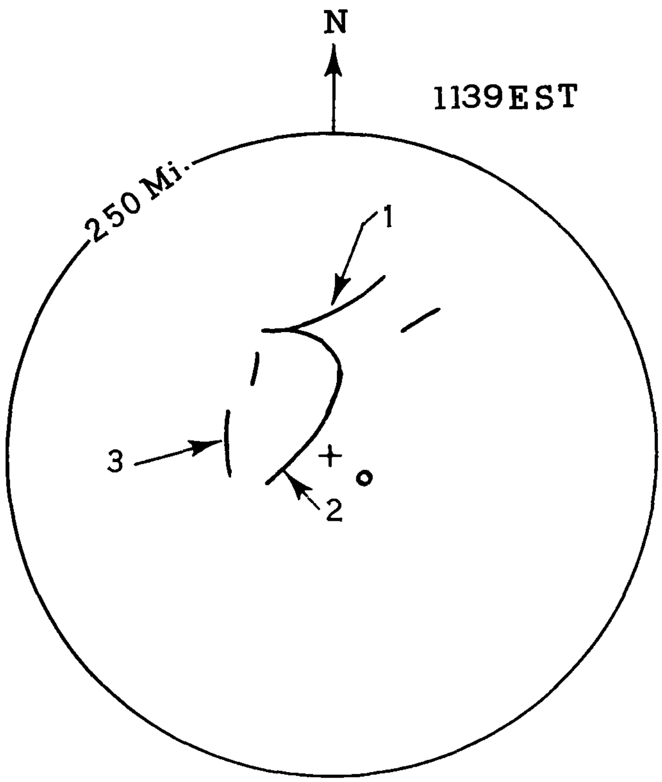


FIGURE 7.—Sketch of echo lines on WSR-57 PPI scope, Washington National Airport, September 3, 1961, 1139 EST. 250-nautical mile range. Numbers label significant lines in order of their intensity. Small circle indicates camera location.

radar at Washington National Airport,[4] and the hourly surface weather observations for the area within about 200 miles of the camera location. The standard surface synoptic map for 1300 EST September 3, 1961, shows only high pressure predominating over the area with no frontal activity; i.e., an "air mass" situation.

A sketch of the radar echo lines on the PPI scope (250-mile range) at 1139 EST is given in figure 7. The significant echo lines are numbered 1, 2, and 3, in order of their intensity. The positions of these three lines, at approximately half-hourly intervals, are shown in figure 8, as they appeared on the PPI scope with 100-nautical mile range setting. Line 1, the primary line, oriented east-northeast to west-southwest, moved toward the south-southeast at an average speed of 28 kt., accelerating toward the end of the period. Line 2, oriented north-east-southwest, moved southeast at an average speed of only 5 kt. Line 2 became smaller with time, and dissipated after 1405 EST (position D). Line 3, oriented northwest-southeast, moved erratically toward the north-east, at an average speed of 9 kt.; however, the continuity of this line was very difficult to follow. Probably several lines were forming and dissipating, and "line 3" should not be interpreted as one well-defined continuous line (as was line 1). The line shown at position G of line 3 first appeared as a new line at 1510 EST; it parallels position F but is too far ahead to be the same line.

[4] The WSR-57 radar operates at a wavelength of 10 cm. and has a peak power output of 500 kw. Maximum range is 250 nautical miles using a 4 microsecond pulse length; beamwidth is 2°. Unfortunately, no photographs were taken on short range and ½ microsecond pulse length, and the radarscope camera was malfunctioning, sometimes taking only a portion of the full PPI circle. Nevertheless, some useful data were obtained.

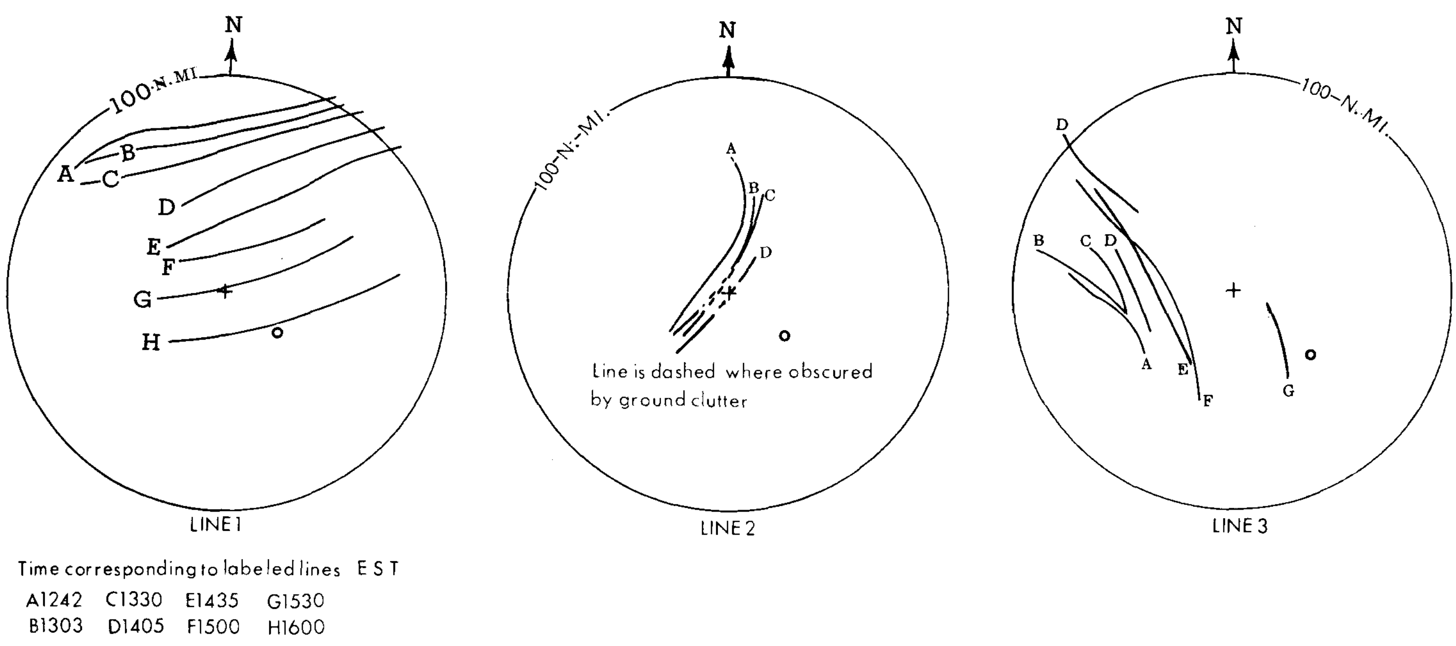
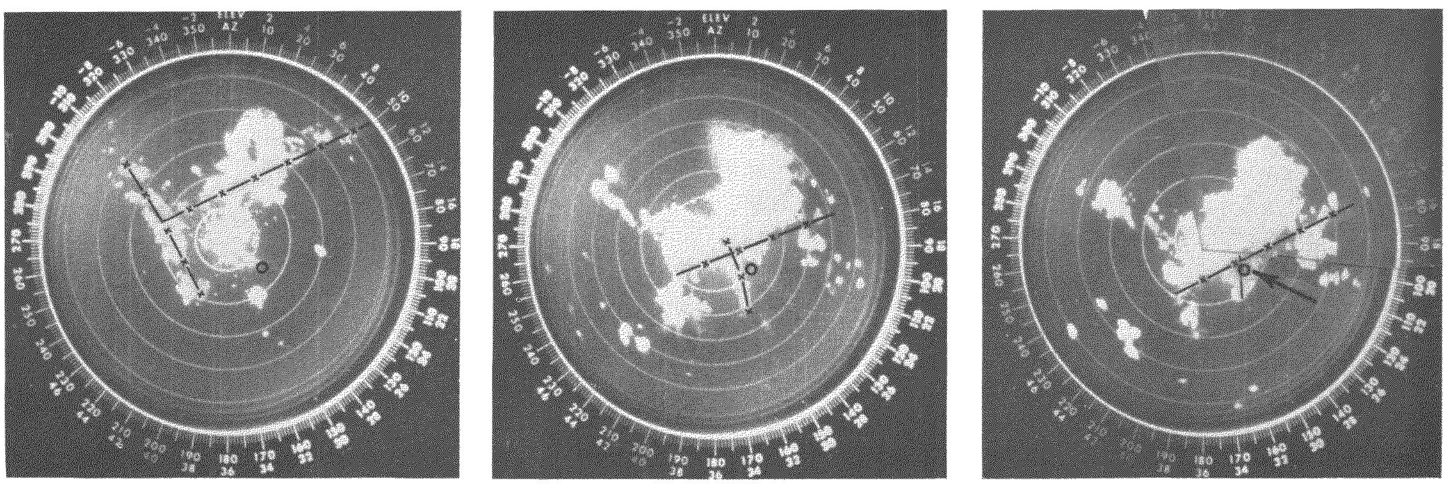


FIGURE 8.—Positions of the three significant radar echo lines. Data same as figure 7 except 100 nautical mile range and times indicated by legend.

The radarscope photographs reveal that at several times the echo lines intersected each other. Figure 7 shows the first such occurrence: lines 1 and 2 intersect at approximately 100 nautical miles north of the radar site. The intersection of lines 1 and 3, at 1435 EST (position E of fig. 8), is shown in the radarscope photograph (fig. 9a). The lines intersect at approximately 295°/38 nautical miles from the radar site. At 1500 EST (position F fig. 8) the intersection is at 295°/30 nautical miles. At 1530 EST, one could estimate the intersection of lines 1 and 3 at 090°/10 nautical miles; however, as illustrated by figure 9b, the "spreading out" of line 1 by this time makes the determination of line positions very difficult. Figure 9b also shows that the character of the precipitation in the northeast quadrant had become more stratiform. The appearance of the PPI scope at approximately 1600 EST, when the cloud photographs were taken, is shown in figure 9c.[5] The intersection of line 1 and the remains of line 3 appears to be at 135°/20 nautical miles. The location where the cloud photographs were taken is 128°/31 nautical miles from the radar site.

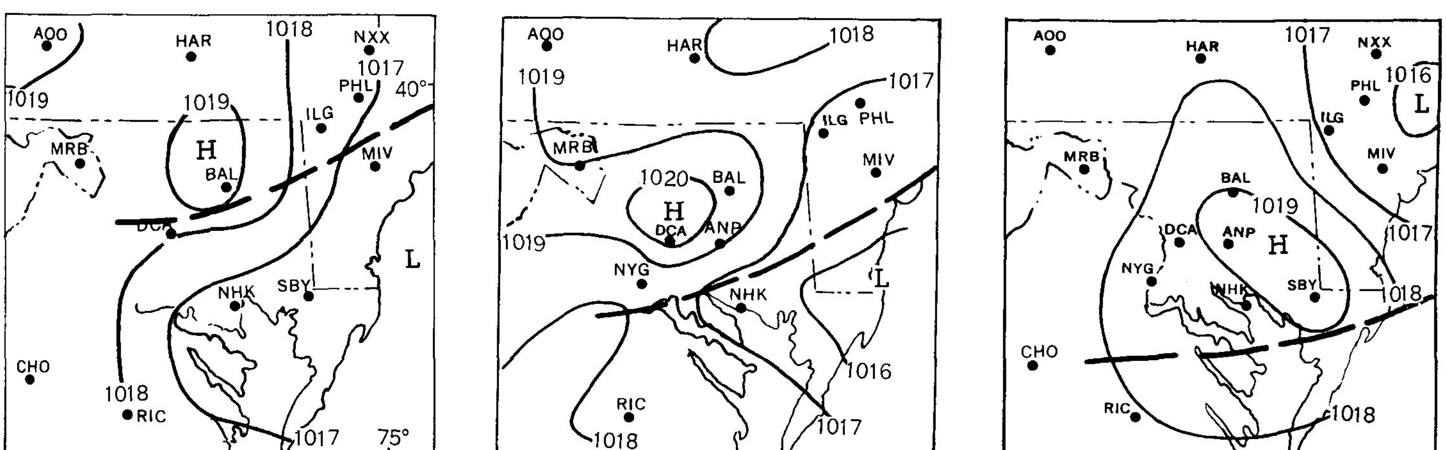
While no pictures are available of the RHI scope of the WSR-57, which would show the vertical structure of the echoes, a notation by the radar observer on duty indicates tops of the echo in the vicinity of the arcus and funnel clouds were at 49,000 feet; this was also the tropopause height as indicated by the 1900 EST sounding at Sterling, Va. (49 nautical miles northwest of the camera location).

[5] Figure 9c was made from two exposures; the portion from 344° through 097° was taken at 1603 EST, the remainder at 1558 EST. Full circle picture was not available.



a 1435 EST b 1530 EST c 1650 EST

FIGURE 9.—Photographs of the WSR-57 PPI scope, Washington National Airport, September 3, 1961, 100-nautical mile range. Axes of echo lines indicated by x–x. Small circle indicates camera location. (a) 1435 EST; (b) 1530 EST; (c) 1600 EST—arrow indicates location of arcus and funnel clouds.



a 1500 EST b 1600 EST c 1700 EST

FIGURE 10.—Mesoanalysis of surface weather, September 3, 1961. Pressure contours labeled in millibars. Dashed line shows position of primary instability line. (a) 1500 EST; (b) 1600 EST; (c) 1700 EST.

Analysis of pressures from hourly surface weather observations between 1200 and 1800 EST, at 1-mb. intervals, revealed the presence of a meso-High, from 1500 to 1700 EST behind line 1. Figure 10 shows that the High moved toward the south at about 30 kt. between 1500 and 1600 EST, and toward the southeast at 30 kt. in the following hour. Barograph traces at the Weather Bureau Central Office at Washington, D.C., show a 2-mb. pressure jump at 1530 EST with pressure remaining high until 1630 EST.

Although widespread thunderstorm activity accompanied the primary instability line,[6] the only other severe weather reported in the area was a gust to 52 kt. at Baltimore (between 1500 and 1600 EST); also a "violent" hailstorm, "strong" winds, and "torrential" rains caused extensive damage to tobacco crops on a farm 22 nautical miles west-northwest of the camera location in figure 1, but the time given was "afternoon."

4. SUMMARY AND CONCLUSIONS

Review of time lapse film of the WSR-57 PPI scope at Washington National Airport revealed that three separate radar echo line systems had been active within a 250-nautical mile radius of the radar site. Only one of these lines (line 1 of fig. 8) was sufficiently prominent to appear on hourly meso-scale surface weather charts. A meso-High to the rear of the primary instability line could be recognized on three consecutive hourly surface maps.

Line intersections were observed on three different occasions: one intersection was estimated to be approximately 10 nautical miles west-northwest from the location of the arcus and funnel clouds at the time of observation, and 10 nautical miles east of an area of crop damage resulting from severe weather. Possibly there is a relation between the occurrence of the funnel and arcus clouds and the intersection of the two instability lines; this hypothesis is supported by the work of Magor [2], who has related certain tornado occurrences with meso-Lows; and in turn has depicted these meso-Lows either by the intersection of two instability lines or by the intersection of a line with a northeastern boundary of rain-cooled air. Also Tepper [3] has shown how the intersection of two pressure-jump lines can be an important factor in tornado development.

Radar data indicate that the intersection of two instability lines probably occurred in the vicinity of the cloud phenomena; also the author observed that the cloud phenomena moved from north to south, followed by a light rain shower and severe cloud-to-ground lightning which moved from west to east. These two facts lead to the conclusion that the extremely unstable conditions, as evidenced by the unusual cloud phenomena, can be at least partially attributed to the intersection of two instability lines, or the intersection of one instability line with cold air associated with a meso-High.

[6] The term "primary instability line" refers to a line determined by the position of radar echo line 1 observed on the WSR-57 PPI scope at Washington National Airport, the hourly and special surface observations within about 200 n. mi. of the camera location, and an observation of a "fine line" observed on the WSR-57 PPI scope at Atlantic City, N.J. The positions of this line are shown in figure 10

ACKNOWLEDGMENT

The fine job of compositing the four photographs of figure 3 was accomplished by Mr. Exum R. Roberts, of the Drafting Section, U.S. Weather Bureau Central Office, Washington, D.C.

REFERENCES

1. World Meteorological Organization, *International Cloud Atlas*, Abridged Atlas, 1956, (p. 14).
2. Bernard W. Magor, "Mesoanalysis: Some Operational Analysis Techniques Utilized in Tornado Forecasting" *Bulletin of the American Meteorological Society*, vol. 40, No. 10, Oct. 1959, pp. 499–511.
3. Morris Tepper, "On the Origin of Tornadoes," *Bulletin of the American Meteorological Society*, vol. 31, No. 9, Nov. 1950, pp. 311–314.